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CAUDAMMINA GUTTA, A NEW SPECIES OF HORMOSINELLIDAE (FORAMINIFERIDA) FROM THE RUPELIAN OF SICILY (ITALY)

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Abstract. A new species of agglutinated foraminifer, *Caudammina gutta* n. sp., is described from Lower Oligocene (upper Rupelian) strata of the Caltavuturo Formation near Portella Colla in the Madonie Mts. (northern Sicily). The new species comes from assemblages rich in deep-water agglutinated foraminifers (DWAF). Biometrical data based on two populations of the new species are compared with the species currently referred to the genus *Caudammina*, as yet known from the Tithonian to the Middle Eocene. *C. gutta* n. sp. has a large-sized pyriform test and is the end-member of a Cretaceous-Paleogene lineage which is interpreted as an example of size increase in time conforming to Cope's rule.

Riassunto. Una nuova specie di foraminifero agglutinante, *Caudammina gutta* n. sp., viene descritta dall'Oligocene inferiore (Rupeliano superiore) della Formazione di Caltavuturo, affiorante presso la località di Portella Colla nelle Madonie (Sicilia settentrionale). La nuova specie proviene da associazioni a foraminiferi bentonici dominate da foraminiferi agglutinanti di acque profonde (DWAF). Dati biometrici ricavati su due popolazioni della nuova specie permettono il raffronto in base al diametro ed altezza del guscio e al diametro del colletto con le altre specie del genere *Caudammina*, finora noto dal Titonico all'Eocene medio. *C. gutta* n. sp. ha un guscio piriforme e di grandi dimensioni e può rappresentare il termine ultimo di un trend evolutivo in accordo con la cosiddetta regola di Cope.

Introduction

In the Oligocene clays of central-northern Sicily assemblages consisting mainly of deep water agglutinated foraminifera (DWAF) were found (Benedetti & Pignatti 2008). The knowledge of Paleogene DWAF from the Mediterranean Neotethys is still incomplete, especially for the Oligocene; this finding is thus particularly important because it provides new data on Rupelian DWAF assemblages from Italy.

The aim of this work is to investigate the systematics and biometry of a new species of *Caudammina* (Hormosinellidae). The new species is compared biometrically with the species-rank taxa currently referred to *Caudammina* (Grzybowski 1898, 1901; Bukowy & Geroch 1956; Geroch 1959, 1960, 1967; Bubík 1977, Rögl 1995).

Geological setting

The investigated assemblages belong to clayey layers of the Caltavuturo Formation (Schmidt di Friedberg et al. 1960) cropping out at Portella Colla. The outcrop is located in the Regional Park of the Madonie Mts., 20 km south of Cefalù (Province of Palermo), between Monte dei Cervi and Monte Mùfara (Fig. 1).

The Caltavuturo Formation of the Imerese Domain in the eastern Madonie Mts. consists of a sequence of red and dark grey clays with interbedded calcareous turbiditic layers.

At Portella Colla the Caltavuturo Formation conformably overlies the Crisanti Formation and the contact is interpreted as erosional (Grasso et al. 1978); the thickness of the best exposed section is about 30 m and its age is Late Eocene-Early Oligocene. Upsection, in the Portella Colla Clay, silicoclastics gradually increase and calcareous levels disappear (Wezel 1966; Benedetti & Pignatti 2008).

The fossil assemblages within the carbonate breccia layers are clearly displaced by gravity flows. These

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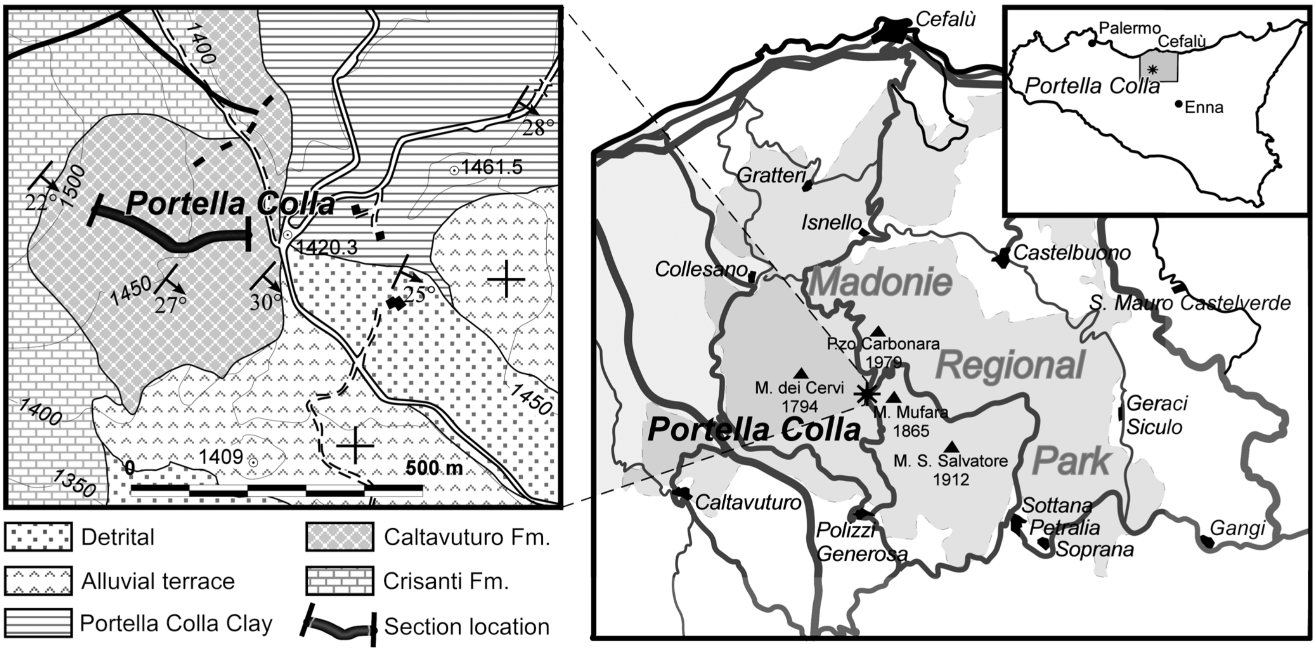

Fig. 1 - Outcrop location and schematic geological map of the investigated area.

levels consist mainly of tests of Oligocene larger foraminifera, among which are borelids and nummulitids, along with other foraminifera, calcareous red algae, and fragments of bryozoans and corals. Reworked Cretaceous orbitoids sporadically occur exclusively in the turbiditic layers.

The clayey levels are red in the lower part of the section, whereas upwards they gradually become greenish gray.

The two populations investigated biometrically come from a 10 m thick interval of the upper part of the Portella Colla section (samples MM12 and MM14; Fig. 2).

According to the Shallow Benthics Zonation (SBZ: Cahuzac & Poignant 1997; Serra-Kiel et al. 1998), the FO of *N. vascus* Joly & Leymerie, 1848 marks the lower Rupelian (SBZ 21), and the FO of *N. praemarginata* (Douvillé, 1908) and *Eulepidina formosoides* (Douvillé, 1924) marks the upper Rupelian (SBZ 22A). In the clays low abundance DWAF assemblages are present, with rare benthic hyaline taxa such as *Cibicidoides* and rare planktic foraminifers. These assemblages have been interpreted as bathyal (Benedetti & Pignatti 2008), indicating deposition beneath a locally raised CCD, although a greater (i.e., abyssal) depth cannot be excluded. *Caudammina* is abundant in the poorly oxygenated levels marking the upper Rupelian.

Planktic foraminifera are scarce and poorly preserved. The forms which could be determined belong to the *Globoquadrina tripartita-G. tapuriensis* group, marking the Oligocene. The succession is barren of calcareous nannoplankton, probably because of dissolution and silicization. Moreover, according to the absence of reworked Cretaceous forms among the agglutinated foraminifera and because the DWAF assemblages show a coherent vertical distribution, it may be assumed that the specimens of *Caudammina* are not reworked.

Materials and methods

The samples containing *Caudammina* assemblages were dried, weighed, treated with hydrogen peroxyde and tensides to disgregate the consolidated sediments, wet-sieved through 63 µm and 125 µm screens and dried. *Caudammina* specimens, which occur only in the >125 µm residue, were mounted into standard micropaleontological slides for counting and documentation.

Each specimen was photographed at incident light with a Nikon Coolpix E990 digital photocamera mounted on an Olympus SZX12 stereoscopic microscope. Selected specimens were observed and photographed at a FEI Quanta 400 MK2 scanning electron microscope (SEM).

Biometrical data were measured on digital photographs by vectorial computer software and transcribed on a Microsoft Excel sheet to perform statistical analysis and graphical scatter diagrams.

The type specimens of the new species described herein are deposited in the micropaleontological collection of the Museum of Paleontology, Department of Earth Sciences, “La Sapienza” University, Rome (MPUR, NS152.1-11).

The genus *Caudammina*

Diagnostic features. Test free, subspheric, oval in outline, multilocular, with uniserial pseudochambers (i.e., in which true septa between chambers are absent) connected by a tubular neck. Wall thick, finely agglutinated; cement siliceous, presumably organic before fos-

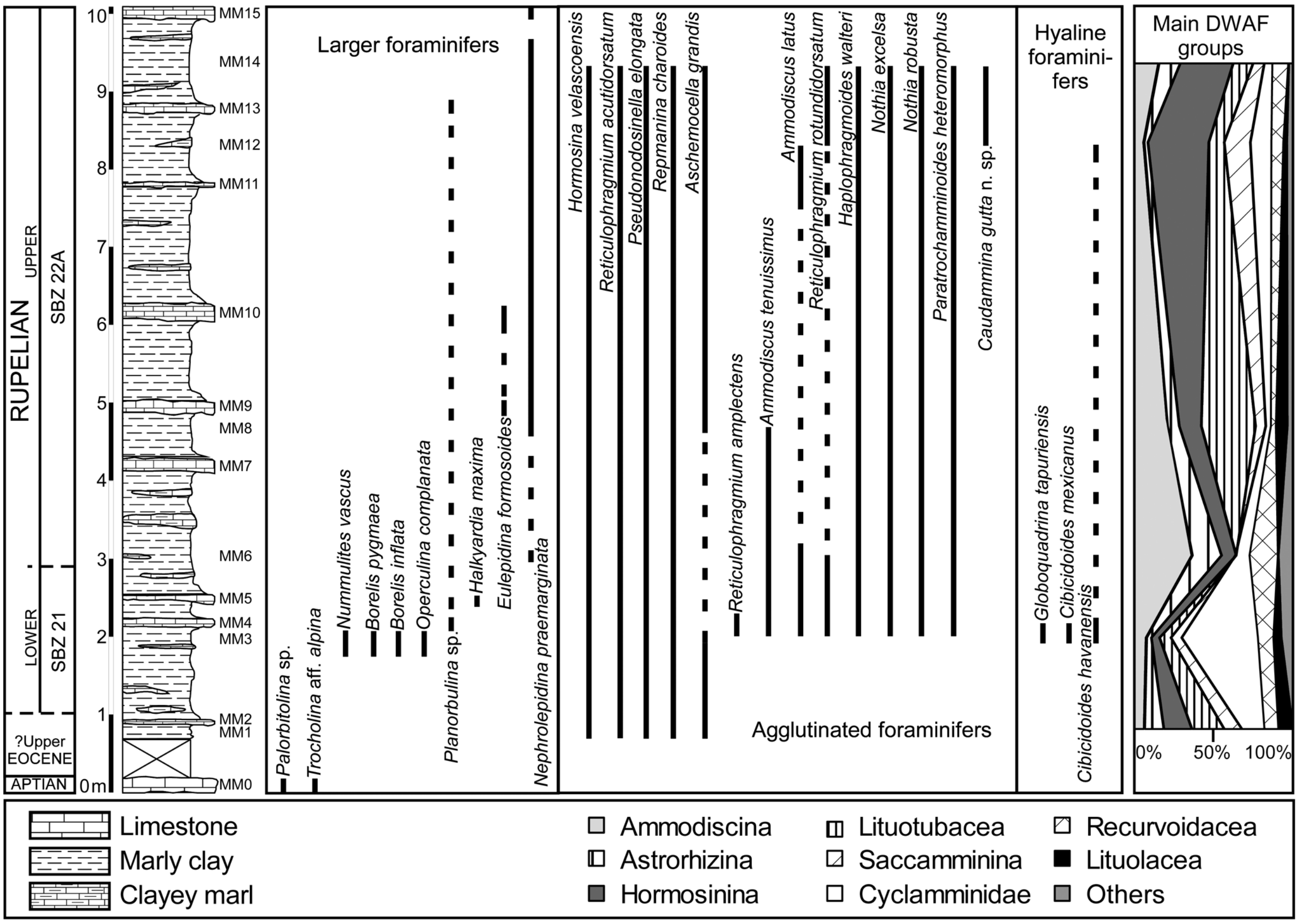

Fig. 2 - Stratigraphic section and distribution of the main taxa. The presence of Upper Eocene strata is uncertain. Benthic perforate foraminifers and planktic foraminifera are very rare or absent.

silization; surface smooth. Aperture terminal, at the end of a tubular neck. First chamber with a single aperture.

Remarks. Montanaro-Gallitelli (1955) described a new species as "*Saccammina*? *caudata*" and conditionally proposed it as the type species of the new genus *Caudammina*. Loeblich & Tappan (1964) considered *Caudammina* as synonym of *Pelosina* Brady, 1879; later Loeblich & Tappan (1987) regarded it as genus of uncertain status. Kuhnt & Kaminski (1990) and Kaminski (2000) interpreted *Saccammina caudata*, the type species of *Caudammina*, as is identical with *Reophax ovulum* Grzybowski, 1896 (Fig. 3).

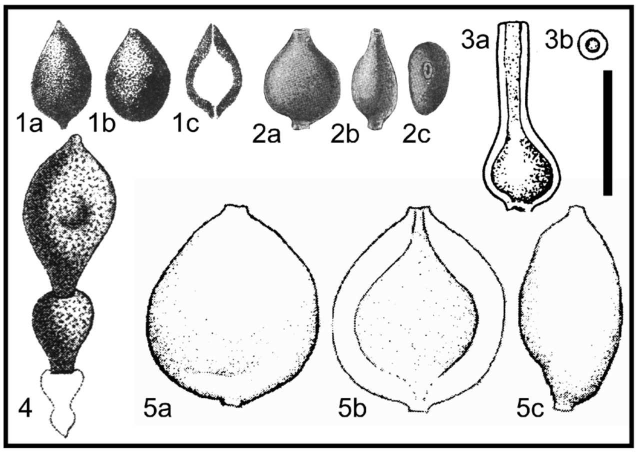

Fig. 3 - Species-rank taxa currently referred to *Caudammina*, as originally illustrated: 1a-c) *Reophax ovulum* Grzybowski, 1898; 2a-c) *Saccammina caudata* Montanaro-Gallitelli, 1955 from Montanaro-Gallitelli (1958); 3a-b) *Hormosina ovulum crassa* Geroch, 1967; 4) *Reophax ovuloides* Grzybowski, 1901; 5a-c) *Hormosina ovulum gigantea* Geroch, 1960. Scale bar = 0.5 mm.

Myatlyuk (1966) designated *Reophax ovulum* as type species of *Carpathiella* according to its wall interpreted as cryptocrystalline siliceous (this feature is presumably a diagenetic effect). *Carpathiella* was included among the foraminiferal genera of uncertain status by Loeblich & Tappan (1987). Hanzlíková (1966) erected the genus *Rothina* with type species *Rothina silesica* Hanzlíková, 1966, which Bubík (1997) recognized as senior synonym of *Caudammina crassa* (=*Hormosina crassa* Geroch, 1967). Bubík (1997) also demonstrated that the genera *Rothina* and *Carpathiella* are younger synonyms of *Caudammina*. Detailed observations on *R. silesica* by Bubík (1997) confirm that its pseudochambers are free and internally undivided, and that it grows around sponge spicules. Finally, the genus *Caudammina* has been reinstated by Rögl (1995), Kaminski (2000) and Kaminski & Gradstein (2005); it is currently known as a cosmopolitan genus ranging from the Tithonian (Bubík 1997) to the Middle Eocene (Kaminski & Gradstein 2005). The only possible Oligocene record of the genus is from the Congo Fan, offshore Angola, by Kender et al. (2008), who postulate that their specimens are reworked.

Rögl (1995) demonstrated that *Ataxophragmium arenaceum* Karrer, 1866 belongs to *Caudammina* and that it is the valid senior synonym of *Hormosina ovulum* (Grzybowski) *gigantea* Geroch, 1960 (Fig. 3). Kaminski & Gradstein (2005) argued that the name *A. arenaceum* is a *nomen oblitum* in the sense of the second edition of the International Code of Zoological Nomenclature. However, according to the fourth edition of the Code, in force since 1 January 2000, the suppression of *A. arenaceum* in favour of *H. ovulum giganteum* proposed by Kaminski & Gradstein (2005) is invalid and therefore in the present work we employ the name *Caudammina arenacea* (Karrer), as suggested by Rögl (1995).

Caudammina ovulum (Grzybowski) is similar to *C. arenacea* (Karrer) especially in the form and structure of the test, but it is smaller (200-400 µm) and its pseudochambers are longer. *C. arenacea* (Karrer) has a limited stratigraphical range, being restricted to the Maastrichtian (Geroch 1959; Geroch & Nowak 1984). Elongated forms belonging to *C. ovuloides* (Grzybowski) range from the ?Turonian through the Middle Eocene (Kaminski & Gradstein 2005).

Biometry

Geroch (1959) proposed dimensional parameters such as diameter, height of test and thickness of the neck for distinguishing Paleocene populations of *Caudammina.* Rögl (1995) subdivided *C. ovulum* into subspecies according to test size, whereas Bubík (1997) analysed *C. silesica* and *C. ovulum* populations using test and neck diameter.

For this study we investigated biometrically 62 specimens from Portella Colla: 27 from sample MM12, 35 from sample MM14. In addition, 125 specimens of *Caudammina* described in the literature were taken into account: 51 *Caudammina ovulum* and 22 *C.* cf. *ovulum* from the Paleocene of the Carpathians (Geroch 1959), 4 *C. ovulum* from the Maastrichtian of the Carpathians (Bukowy & Geroch 1956), 18 *C. ovuloides* from the Upper Cretaceous and Paleogene (Jednorowska 1975; Kaminski & Geroch 1993; Kaminski & Gradstein 2005; Kaminski et al. 1988; Kuhnt 1990; Kuhnt & Collins 1996; Kuhnt & Urquhart 2001), 8 *C. silesica* from the Barremian-Senonian of the Carpathians (Geroch 1967), 4 *C. silesica* from the Cretaceous (Holbourn & Kaminski 1995; Kuhnt & Urquhart 2001), 4 *C. arenacea* from the Maastrichtian of Godula beds (Silesian Carpathians) (Geroch 1960) and from the Campanian of southern Spain (Kuhnt 1990), 2 *C. ovulum* (described as *Saccammina caudata*) from the Senonian of the Northern Apennines (Montanaro-Gallitelli 1955, 1958) and 12 *C. ovulum* measured from various works (Kaminski et al. 1988; Kuhnt 1990; Kuhnt & Collins 1996; Geroch 1960, 1967). For this purpose, we digitized the x and y coordinates of 99 specimens plotted in scatter diagrams by Rögl (1995) and Bubík (1997).

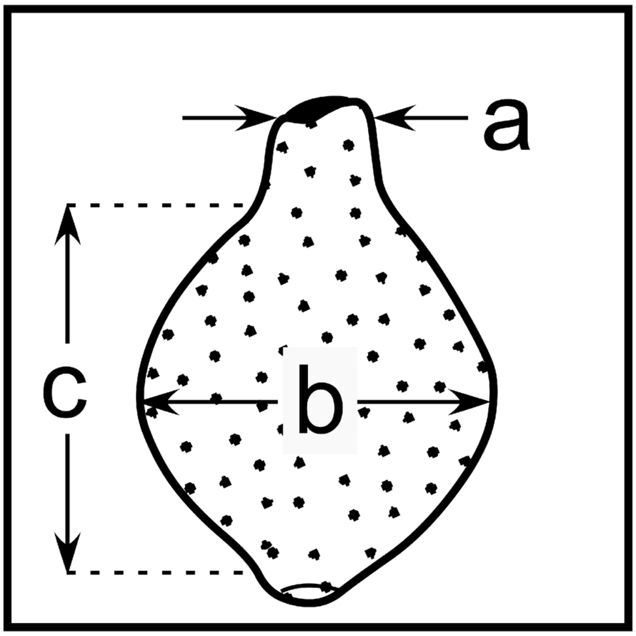

Fig. 4 - Schematic drawing of *Caudammina*; a) diameter of the principal neck, b) diameter of test, c) height of the test.

For every specimen we measured 3 parameters and 2 indexes. Parameter a: diameter of the neck; parameter b: maximum diameter of the test; parameter c: height of the test (this measure is taken without considering the height of the collar and the secondary opening, as in Fig. 4); index b/a: ratio between diameter of the test and diameter of the neck; index c/d: degree of test lengthening.

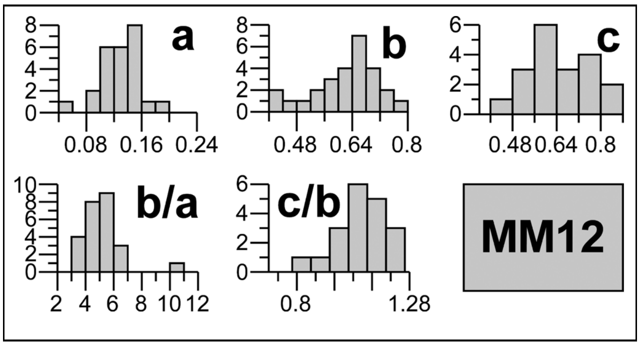

Fig. 5 - Frequency histograms of the parameters a (n=25), b (n=27), c (n=19) and the indexes b/a (n=25) and c/b (n=19) in the population MM12 (n=27).

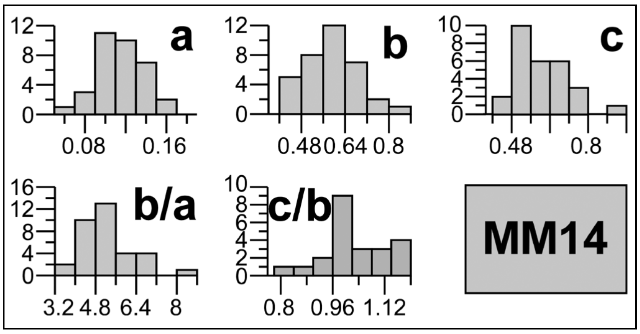

Fig. 6 - Frequency histograms of the parameters a (n=34), b (n=35), c (n=29) and the indexes b/a (n=34) and c/b (n=29) in the population MM14 (n=35).

Geroch (1959) firstly applied the biometric method to *Caudammina* populations and introduced the parameters a, b, c and the ratio b/a. According to the biometrical values of b and c, he distinguished in a population of *Hormosina ovulum* (Grzybowski) "a forms" (= *C. arenacea*) and "b forms" (= *C. ovulum*), the first ones having higher values. Basing on the b/a ratio, he also distinguished atypical forms that he called *H.* cf. *ovulum* (= *C. silesica*) according to the following biometric ranges:

b/a = 5.5-8.0 *H. ovulum* (= *C. ovulum*)
b/a = 2.5-4.0 *H.* cf. *ovulum* (= *C. silesica*)

We calculated the three parameters for all the specimens listed above, and compared the values obtained with those for the two populations from Portella Colla. The dimensional parameters were then plotted in a scatter diagram according to Rögl (1995) and Bubík (1997). Each point in the scatter diagrams was digitized using the Microsoft Excel utility Grab.it (Datatrend Software) to obtain the x and y coordinates, and the values were

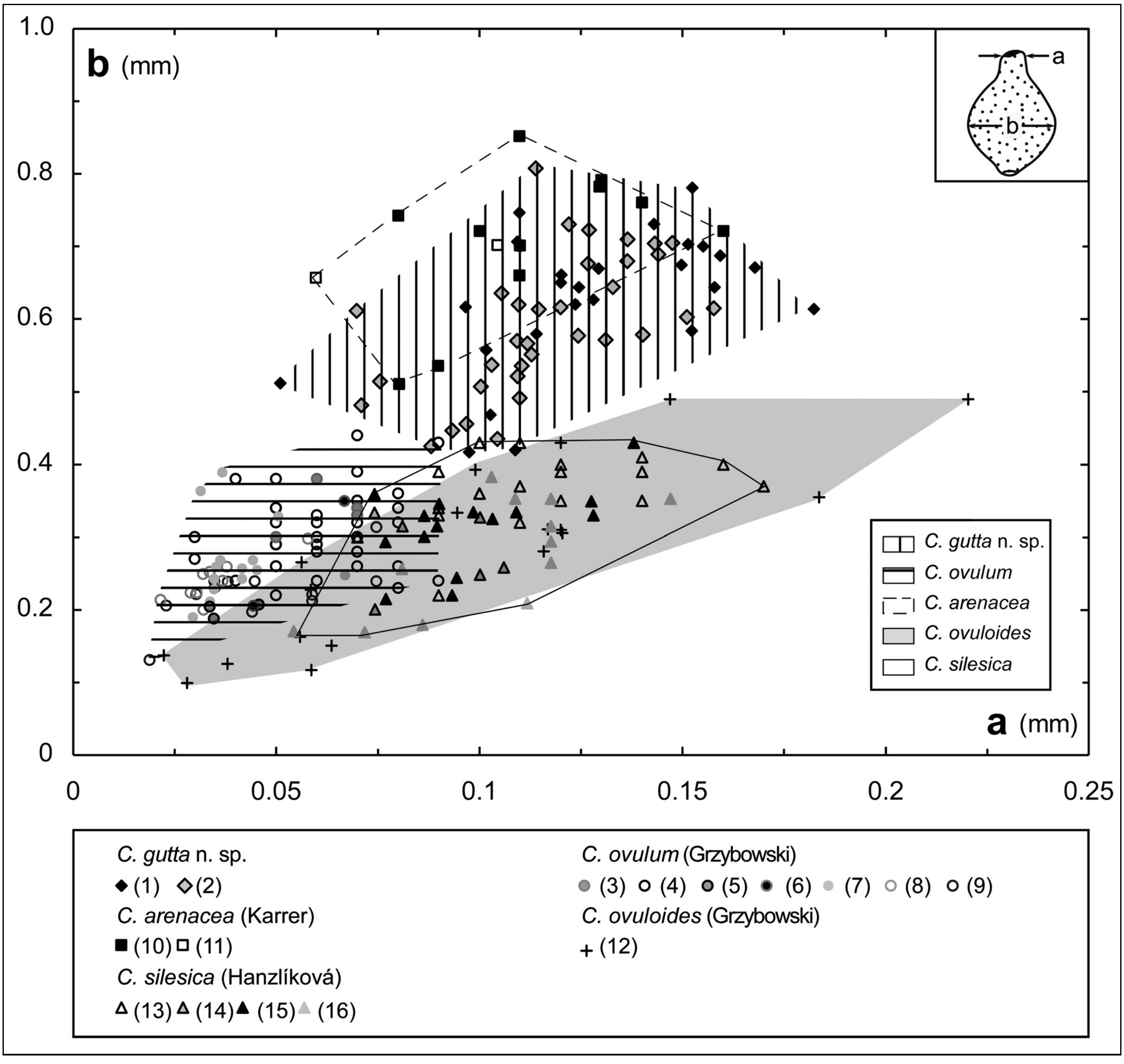

Fig. 7 - a vs. b scatter diagram (including data from Bubík 1997).

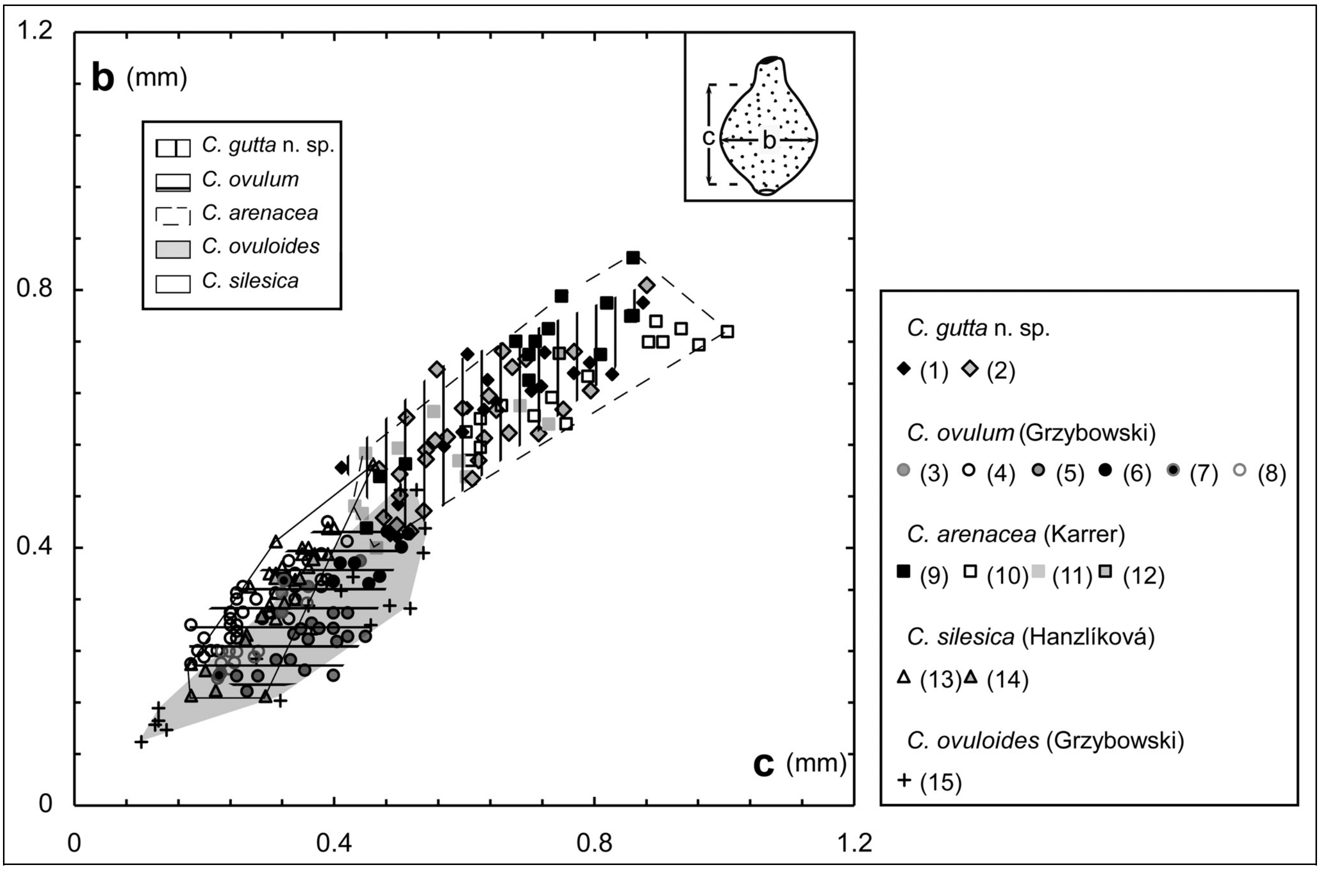

Fig. 8 - b vs. c scatter diagram (including data from Rögl 1995).

plotted in new scatter diagrams for systematic discussion.

Discussion of biometrical analysis

The frequency histograms of the considered parameters (Figs. 5, 6) show a unimodal and normal distribution underlining the occurrence of homogeneous statistical populations. This strengthens the inference that admixture of different species of *Caudammina* can be rejected. On the other hand, we can exclude that the DWAFs from Portella Colla are reworked from the Cretaceous, according to the composition of the foraminiferal assemblages.

Observing the a vs. b scatter diagram (Fig. 7), the values of *C. silesica* are distinctly set apart. *C. ovulum* has a much wider range, whereas MM12 and MM14 fit in the middle area compared with those described by Bubík (1997). The main differences between *C. silesica* and the remaining species of the genus are the diameter of the neck a and the b/a ratio.

The mean size of MM12 and MM14 populations is distinctly larger than in other *Caudammina* populations described from the Cretaceous and Paleocene of the Alps and the Carpathians, except for *C. arenacea*.

The values of the parameters b and c of *Caudammina gutta* n. sp. from Portella Colla (Fig. 8) overlap in part with those of *C. arenacea*, which becomes extinct at the end of the Maastrichtian (Geroch & Nowak 1984). The index c/b of *C. arenacea* reaches mean values similar to those of the Portella Colla populations (Tab. 1), but the two forms are readily distinguished by the ratio b/a, which reaches a mean value of 5.10 (MM12) and 5.24 (MM14) in the two populations from Portella Colla, whereas in *C. arenacea* it ranges from 1.00 to 1.19. Thus, the new species is easily distinguished biometrically from *C. arenacea*.

Caudammina ovulum is undoubtedly an archaic morphotype, small and rounded, ranging from the Hau-

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PLATE 1

SEM photographs of specimens of *Caudammina gutta* n. sp.: 1. Holotype (MPUR NS152.1); 2-18. Paratypes; 2. MPUR NS152.2; 3. CA07; 4. MPUR NS152.3; 5. CA09; 6. CA08; 7. CA03; 8. AIV ca003; 9. AIV ca001; 10. CA10; 11. MPUR NS152.4; 12. AIV ca004; 13. CA04; 14. MPUR NS152.5; 15. AI ca01; 16. AI ca02; 17. AIV ca002; 18. AIV ca0000. Specimens illustrated in figs. 1, 2, 4, 7, 11, 13, 14, 17, 18 from sample MM14; specimens illustrated in figs. 3, 5, 6, 8-10, 12, 15, 16 from sample MM12. Scale bar = 0.5 mm.


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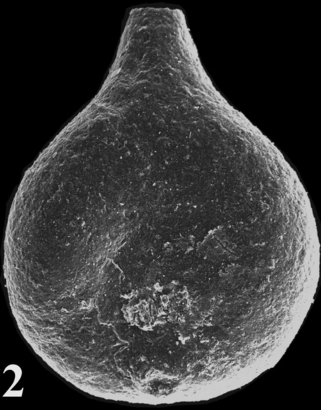
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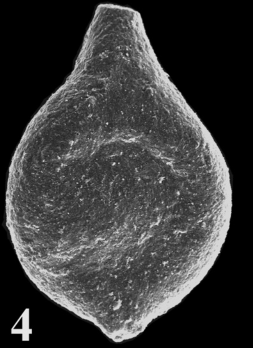
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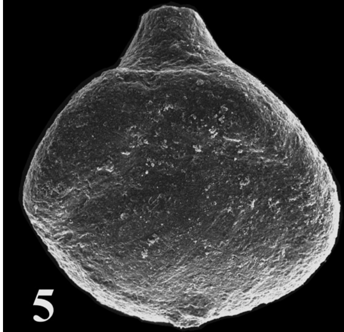
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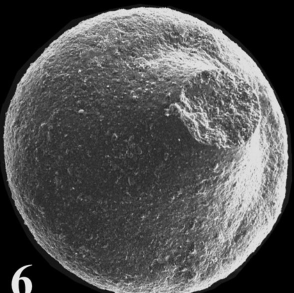
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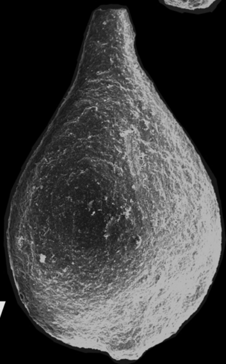
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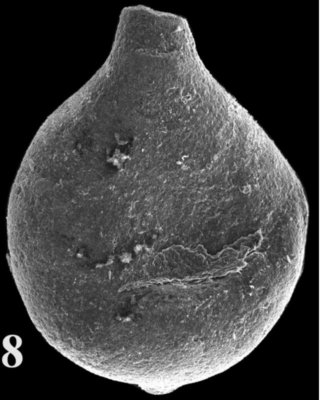
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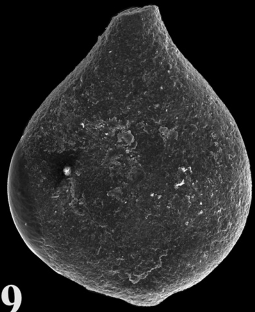
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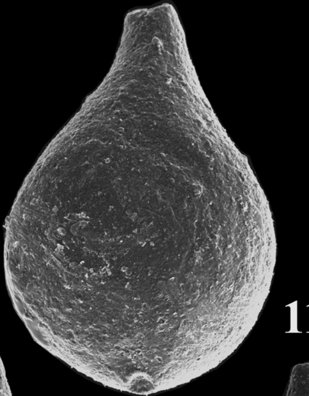
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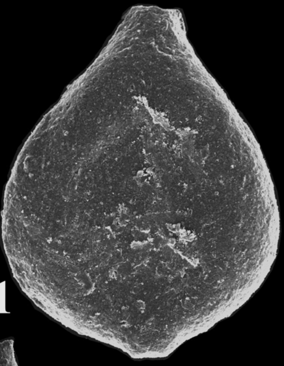
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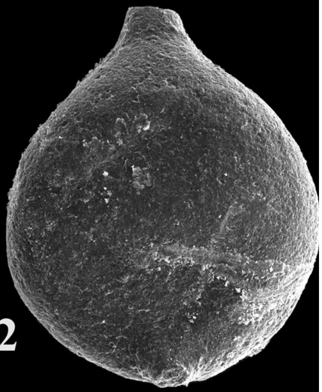
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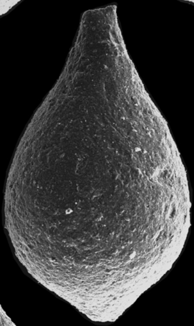
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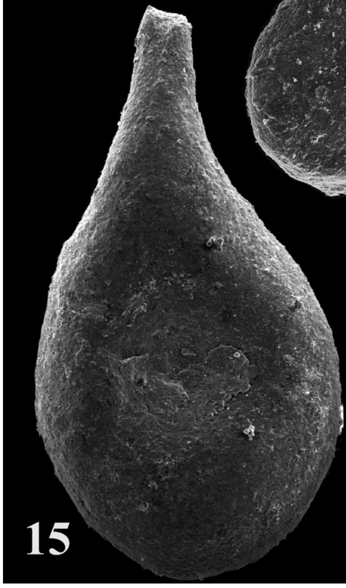
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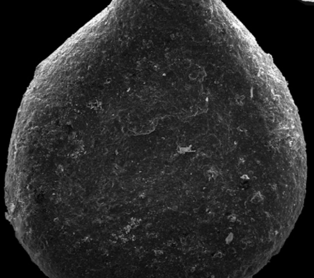
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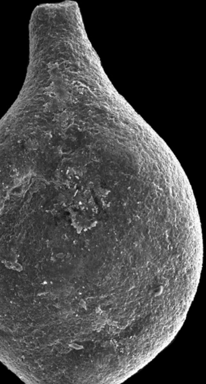
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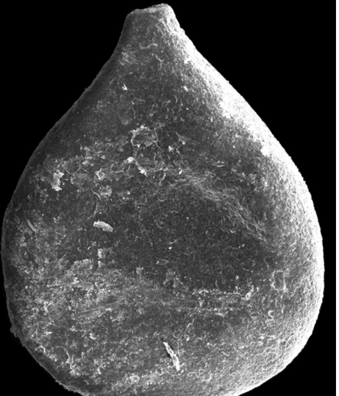
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terivian to the Middle Eocene, according to Kaminski & Gradstein (2005).

Thus, a ghost range for *Caudammina* from the Priabonian to the lowermost Rupelian has to be assumed.

Systematics

We follow the suprageneric classification proposed by Kaminski (2004). In this classification, the Hormosinellidae are placed in the order Lituolida, suborder Hormosinina; the latter include the Hormosinellacea (with pseudochambers, i.e., in which true septa between chambers are absent) and the Hormosinacea (with true chambers). In the classification of Mikhalevich (1995), the Hormosinellidae (i.e., forms with pseudochambers such as *Caudammina*) are placed in the class Astrorhizata Saidova, 1981, order Astrorhizida Lankester, 1885; because, as generally understood, the Astrorhizida include organically-cemented tests only (Kaminski 2004), this attribution is not followed here.

Order **Lituolida** Lankester, 1885

Suborder **Hormosinina** Mikhalevich, 1980

Superfamily Hormosinellacea Rauzer-Chernousova & Reitlinger, 1986

Family Hormosinellidae Rauzer-Chernousova & Reitlinger, 1986

Genus *Caudammina* Montanaro-Gallitelli, 1955

Caudammina gutta n. sp.

Pl. 1, figs 1-18

Origin of the name: From the Latin *gutta*, i.e. drop, relating to the morphology of the specimens; noun in apposition.

Type specimens: Holotype (MPUR NS152.1, pl. 1, fig. 1) and paratypes (MPUR NS152.2 to NS152.10), deposited in the micropaleontological collection of the Museum of Paleontology, Department of Earth Sciences, "La Sapienza" University, Rome.

Type horizon: Upper Rupelian; the holotype and paratypes come from sample MM14 of the Caltavuturo Fm.

Type locality: Portella Colla (Madonie Mts.).

Diagnosis: A large-sized, guttiform species of *Caudammina* possessing a short and thick neck with values of the index b/a ranging from 3.36 to 10.03 (mean: 5.18) and c/b from 0.78 to 1.24 (mean: 1.06).

Description. Test free, large, flask-like, originally plurilocular comprised of rounded or pyriform pseudochambers without internal partitions. Wall thick, imperforate and finely agglutinated with a smooth surface. Aperture at the open end of the short neck.

Size. The holotype measures 905 µm in length, 747 µm excluding the two collars, and 684 µm in width; the diameter of the neck is 104 µm. The diameter of the test ranges from 417 to 807 µm (mean: 600 µm), and the height of the test from 410 to 809 µm (mean: 630 µm). The thick neck measures from 40 to 180 µm (mean: 120 µm).

Stratigraphic range. Upper Rupelian.

Paleoecology. *Caudammina* is currently considered as a typical bathyal to abyssal taxon (Kaminski & Gradstein 2005). At Portella Colla it occurs in assemblages dominated by infaunal agglutinated taxa. The genus has been interpreted as deep infaunal (Jones et al. 2005), shallow infaunal (van den Akkers et al. 2000) or surficial epifaunal active deposit feeder (Kender et al. 2008).

Remarks. *C. gutta* differs from *C. silesica* in possessing a shorter and thinner neck and larger pseudochambers (b/a=3.21-3.42 in *C. silesica*; 5.10-5.24 in *C. gutta*), from *C. ovulum* in having more pyriform and larger pseudochambers, from *C. arenacea* for the mean value of b/a ratio (1.00-1.19 in *C. arenacea*) (Tab. 1), from *C. ovuloides* in possessing a thinner neck and shorter pseudochambers; the index of elongation c/b reaches higher values in *C. ovuloides* (mean: 1.30) than in *C. gutta* (mean: 1.06) (Tab. 1).

	b/a	c/b
C. gutta n. sp.	5.10-5.24	1.06
C. ovulum	5.34-7.23	0.94-1.47
C. ovuloides	3.33	1.30
C. silesica	3.21-3.42	0.92
C. arenacea	6.40-8.02	1.00-1.19

Tab. 1 - Mean values of the indexes b/a and c/b in species currently referred to *Caudammina*.

Cope's rule and the genus *Caudammina*

The earliest species of the genus *Caudammina* is *C. silesica*, which appeared in the Tithonian (Bubík 1997). Berggren & Kaminski (1990) suggested that from *C. silesica*, possibly derived from elongated forms such as *Hyperammina* or *Kalamopsis* with a large and elongated collar, originated *C. ovulum* (= *H. ovulum ovulum* Auctt.) and *C. arenacea* (= *H. ovulum gigantea* Auctt.). *C. arenacea* became extinct at the end of the Cretaceous (Geroch & Nowak 1984; Kuhnt et al. 1998). *C. arenacea* was interpreted by Berggren & Kaminski (1990) as the large-sized end member of the Cretaceous lineage of *C. ovulum*, according to Cope's rule. Berggren & Kaminski (1990) hypothesized that the larger *C. arenacea* was more specialized than its smaller ancestors.

Although Gould (1997) cautioned that Cope's rule is a psychological artefact and is often confused with an increase in variance in size (Jablonski 1997),

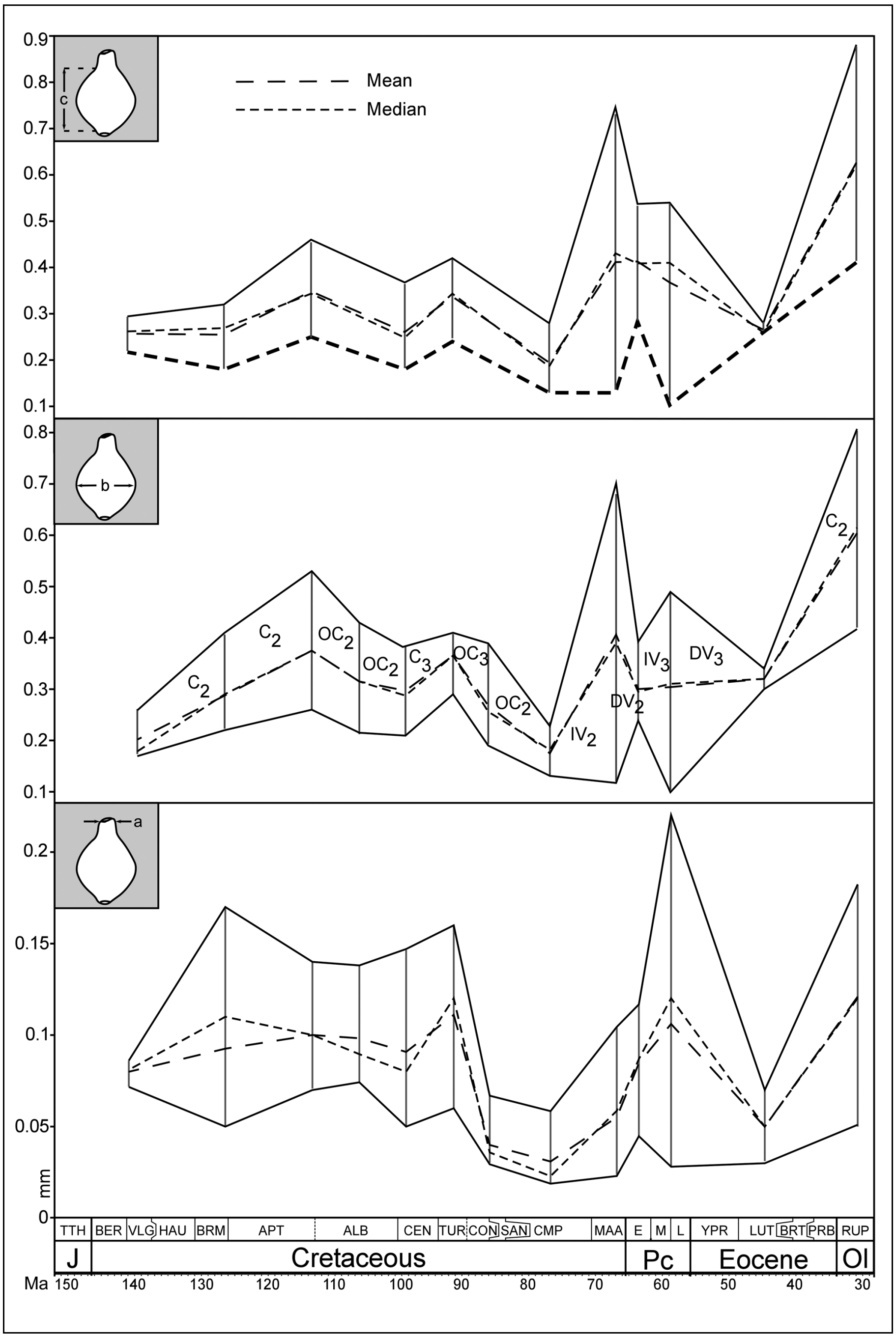

Fig. 9 - Evolutionary trends and type of evolutionary regime (Trammer & Kaim 1999) in *Caudammina* according to parameters a, b and c.

evolutionary increase in size of lineage is a pervasive pattern among foraminifers (Hottinger 1982). Various modes and regimes of size variation in time have been distinguished (Jablonski 1997; Trammer & Kaim 1999). Figures 9 and 10 illustrate size variation in time according to the terminology introduced by Trammer & Kaim (1999). In these graphs we plot the minimum, maximum, median and mean values for *Caudammina* populations from the Valanginian to the Rupelian. Taking into account parameter b, the evolutionary trend in *Caudammina* is marked first by an increase in mean size according to Cope's rule up to the end of the Aptian, then in Albian times there is an opposite trend. At the end of the Cretaceous, from the Campanian to the Maastrichtian, the mean size of diameter abruptly increases in a regime of increasing variance. In this time-span three species of *Caudammina* co-occur: *C. ovulum, C. ovuloides*, and *C. arenacea*, the largest species that disappears close to K/T boundary (Geroch & Nowak 1984; Kuhnt et al. 1998). *C. ovulum* and *C. ovuloides*, interpreted as generalists by Kaminski & Gradstein (2005), reach the Middle Eocene (Kaminski & Gradstein 2005). Considering the Portella Colla populations, the evolutionary trend of the genus *Caudammina* ends with a type of regime of increase of mean size according to Cope's rule. *C. gutta* n. sp. is interpreted as the end member of the Paleogene lineage of *Caudammina*.

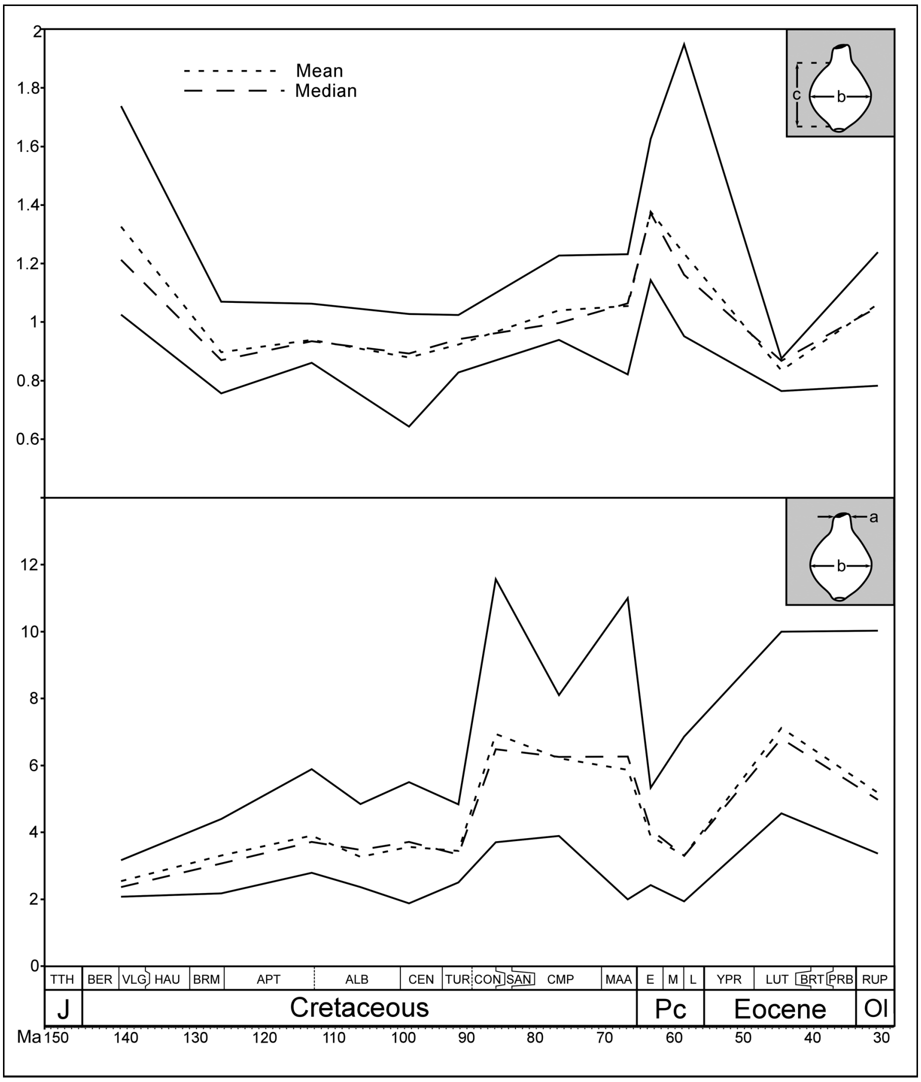

Fig. 10 - Evolutionary trends and type of evolutionary regime (Trammer & Kaim 1999) in *Caudammina* according to the indexes b/a and c/b.

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